Semiclassical Approximations and Predictability in Ocean Acoustics

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LONG-TERM GOAL

Our long-term scientific goal is to understand the basic physics of low-frequency long-range sound propagation in the ocean, and the effects of environmental variability on signal stability and coherence. We seek to understand the fundamental limits to signal processing imposed by ocean variability to enable advanced signal processing techniques, including matched field processing and other adaptive array processing methods.

OBJECTIVES

The objective of the effort described was to initiate the development of a theory of acoustic fluctuations in long-range propagation. This objective is motivated by the failure of traditional approaches (Flatté *et al.*, 1979) to the study of wave propagation in random media (WPRM) to predict measured time spreads and intensity statistics in recent long-range underwater acoustic experiments. The theory being developed builds on a ray-based propagation description. The work involves a combination of ray-based theory, numerical simulations using ray and parabolic equation methods, and analysis of data collected during the Slice89 and AET propagation experiments.

APPROACH

In loose collaboration with F. Beron-Vera (RSMAS), J. Colosi (WHOI), M. Wolfson (APL/UW), S. Tomsovic (WSU), A. Virovlyansky (Nizhny Novgorod) and G. Zaslavsky (CIMS/NYU), the PI has investigated issues relating to the predictability of underwater sound fields. A unifying theme in this work is the notion of ray chaos; in generic range-dependent environments most ray trajectories exhibit chaotic motion. Owing to this chaotic motion, the long-range evolution of individual ray trajectories is not predictable. Although our objective is to understand limitations on the predictability of finite frequency wave fields, the notion of ray chaos is extremely useful inasmuch as it leads to a set of focused questions and provides insight into the wave propagation physics which is difficult to obtain by any other means. Specific topics/questions, which have been investigated by the PI during the past funding cycle, are listed in the following section.

Report Documentation Page

1. REPORT DATE **30 SEP 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Semiclassical Approximations and Predictability in Ocean Acoustics	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Division of Applied Marine Physics,,Rosenstiel School of Marine and Atmospheric Science,,University of Miami,4600 Rickenbacker Causeway,,Miami,,FL, 33149**	8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

WORK COMPLETED

1. Theory review

A review of theoretical results relating to ray and wave chaos, and associated limitations on predictability, has been written (Brown *et al*., 2002).

2. Analysis of the AET experiment

A ray-based analysis (Beron-Vera *et al*., 2002) of measurements made during the AET experiment (Worcester *et al*., 1999; Colosi *et al*., 1999) has been completed. It was shown that in spite of extensive ray chaos, ray-based simulations can correctly account for all of the main features of the measured wavefields including: the overall distribution of acoustic energy in time, depth and angle; travel time spreads in different regions of the wavefield; and intensity statistics in different regions of the wavefield.

3. The ray stability parameter

It was shown (Beron-Vera and Brown, 2002) that ray stability is largely controlled by a simple property of the background sound speed structure, quantified by the alpha parameter (whose definition is based on the action-angle description of ray-motion). Thus rays in environments with identical internal-wave-induced sound speed perturbations but different background sound speed structures may have completely different stability properties.

4. A simple alternative to TRP

It was shown (Brown, 2002) that inverse filter processing (IFP) offers a simple, robust alternative to time reverse processing (TRP), and that IFP techniques should be useful in underwater communication applications.

RESULTS

Although our goal of developing a theory of acoustic fluctuations in long-range propagation has not yet been achieved, significant progress has been made. The forward scattering physics are much better understood than was the case a year or two ago. Perhaps the most important result of the PI's work over the past few years is conceptual: the forward scattering of sound — by internal-wave-induced perturbations, for example — is largely controlled the background sound speed structure, Thus, sound scattering in environments with identical internal-wave-induced sound speed perturbations but different background speed structures may be completely different.

IMPACT/APPLICATION

Our work is contributing to an improved understanding of the basic physics of low-frequency long-range sound propagation in the ocean, and the associated loss of signal stability and coherence imposed by environmental variability. This knowledge contributes to an understanding of the limitations of advanced signal processing techniques, such as matched field processing.

TRANSITIONS

Our results are being used to interpret (reinterpret, in some cases) data collected in long-range propagation experiments, e.g. SLICE89, AET, and the planned 2003 experiment. We are unaware of transitions to system applications.

RELATED PROJECTS

The PI and other members of the "ray dynamics group", listed above, actively collaborate with the NPAL (North Pacific Acoustic Laboratory) groups at SIO (P. Worcester, W. Munk, B. Cornuelle, M. Dzieciuch) and APL/UW (R. Spindle, B. Dushaw, B. Howe, J. Mercer and F. Henyey).

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